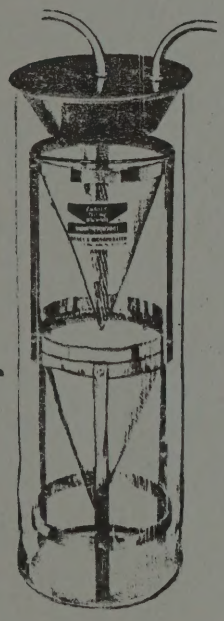
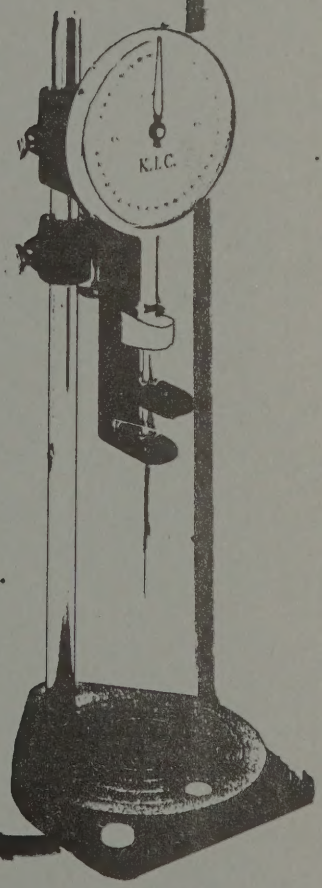


MATERIALS METHOD 5.14



RECYCLED HOT-MIX BITUMINOUS CONCRETE MIX DESIGN

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

MATERIALS BUREAU

MATERIALS METHOD NY 5.14

RECYCLED HOT-MIX BITUMINOUS
CONCRETE MIX DESIGN

January 1985

MATERIALS BUREAU
JAMES J. MURPHY, DIRECTOR

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
1220 WASHINGTON AVENUE, ALBANY, NY 12232

M.A.P. CODE 7.42-1-5.14

TABLE OF CONTENTS

		PAGE
I.	SCOPE	1
II.	GENERAL	1
III.	INFORMATION SOURCES	2
IV.	RECYCLED HOT-MIX DESIGN	
	A. Steps in Design Procedures	
	1. Sampling RAP Stockpile(s)	2
	2. Determine RAP Properties	4
	a) Extraction	
	b) Penetration of Recovered Asphalt Cement	
	3. New Aggregate Gradation	5
	4. Select Blend Percentage	5
	5. Determine Combined Aggregate Gradations	9
	6. Determine Total Asphalt Demand	9
	7. Percent of New Asphalt Required	9
	8. Determine Combined Asphalt Penetration	11
	9. Select New Asphalt Grade	11
	B. Job Mix Formula	14
APPENDIX		
1	EXAMPLE 1 (Using a Known New AC)	15
2	EXAMPLE 2 (Determining the New AC Required)	25

NYSDOT
Library
50 Wolf Road, POD 34
Albany, New York 12232

FIGURE PAGE

1	FLOWCHART	3
2	ASPHALT BLENDING NOMOGRAPH (BR 169)	8
3	RECYCLED MIXTURE DIAGRAM	10
4	ASPHALT BLENDING NOMOGRAPH (BR 169)	12
5	ASPHALT BLENDING NOMOGRAPH (BR 169)	13
6	ASPHALT BLENDING NOMOGRAPH (BR 169)	17
7	RECYCLE MIX DESIGN WORKSHEET (BR 146)	19
8	ASPHALT BLENDING NOMOGRAPH (BR 169)	21
9	RECYCLED MIXTURE SCHEMATIC	22
10	JOB MIX FORMULA (BR 153)	24
11	RECYCLE MIX DESIGN WORKSHEET (BR 146)	27
12	ASPHALT BLENDING NOMOGRAPH (BR 169)	29
13	RECYCLED MIXTURE SCHEMATIC	30
14	JOB MIX FORMULA (BR 153)	32

TABLE

1	RAP STOCKPILE SAMPLE TEST VALUES	15, 25
2	ALLOWABLE RAP BLENDING PERCENTAGES	6
3	MATERIAL DRAW WEIGHTS	20
4	RAP DRAW WEIGHT ADJUSTED FOR MOISTURE CONTENT	23

I. SCOPE

This Materials Method describes the responsibilities and procedures for the preparation and approval of Job Mix Formulae (JMF) for bituminous concrete mixtures which include Reclaimed Asphalt Pavement (RAP). The method outlines a complete procedure to accomplish the following:

1. Sampling of the RAP material.
2. Testing of the RAP samples.
3. Mix design.
4. Required documentation.

II. GENERAL

At present, both technology and equipment exist to satisfactorily accomplish many forms of recycling. However, this method will be confined to hot-mix recycling.

The maximum blend percentage of the RAP is limited by specifications to 70% for drum mix plants and 50% for the batch type plants. However, more realistic production ranges are 30-50% for the former and 20-40% for the latter.

The bituminous concrete producer is responsible for sampling and testing of the RAP, determining the mixture design and submission of all required documentation. The Regional Director or his representative is responsible for reviewing the submitted mix design for completeness and accuracy and is the approving authority.

Once a recycled mix design has been approved, the JMF shall remain valid as long as the RAP properties and blend percentages are unchanged.

III. INFORMATION SOURCES

The following listing makes reference to the various sources of information in addition to this method, that must be consulted in preparing a recycled mix design.

1. Specifications (including all addenda and contract proposal) - Mix Criteria.

2. Approved Aggregate Source Listing - Aggregate Source and Test Numbers.

3. NYSDOT Materials Method 5 - Hot Bin Aggregate Sampling and Sieving Procedures.

4. NYSDOT Materials Method 5.12 - Aggregate Sampling Procedures for Drum Mix Plants.

5. Asphalt Cement and Mineral Filler Supplier - Asphalt Cement penetration and Mineral Filler Gradation.

6. ASTM Test Methods - Supplement the procedures outlined in this method where referenced.

IV. RECYCLED HOT-MIX DESIGN

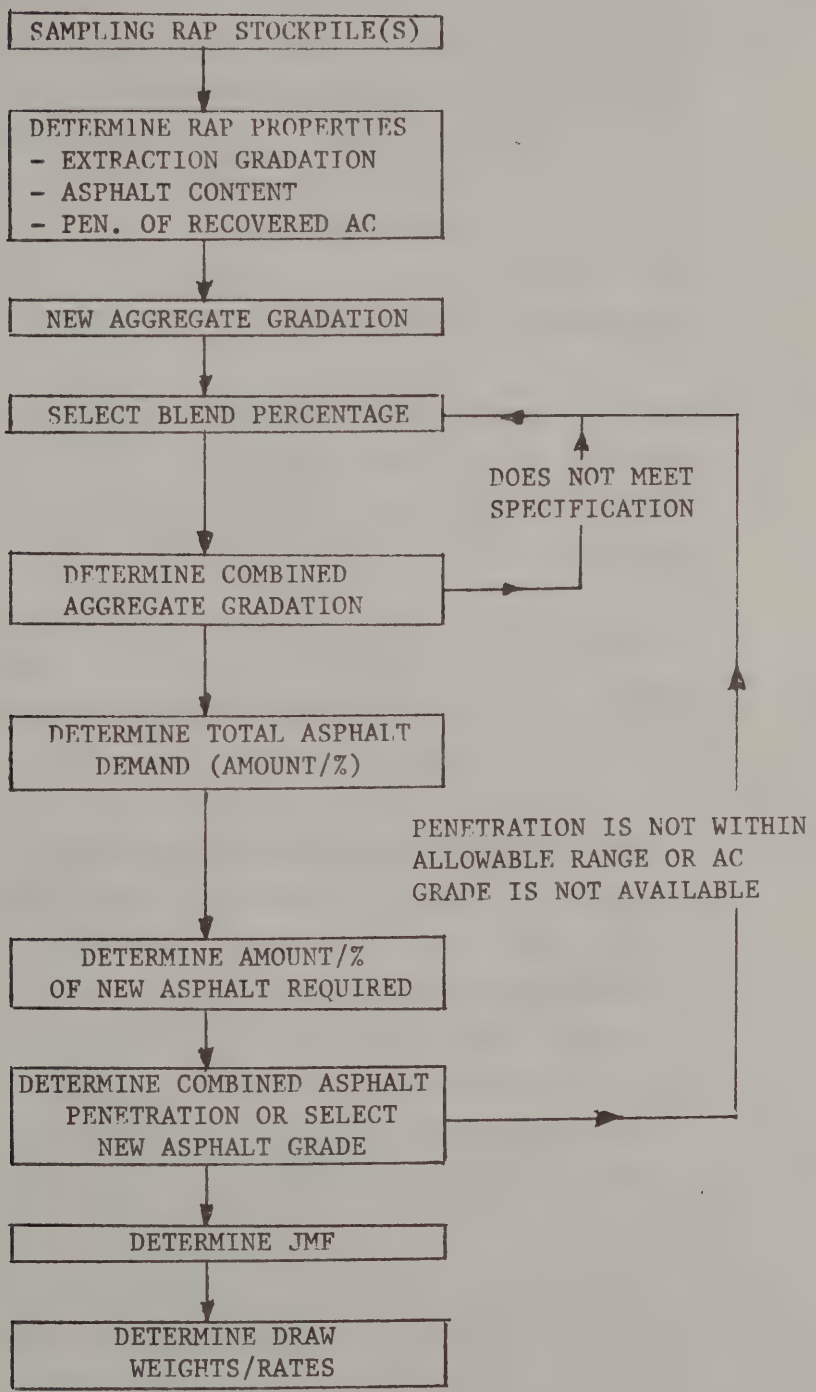
Figure 1 is a flowchart which illustrates the steps that the Producer must take to design a bituminous mixture incorporating RAP.

A. Steps in Design Procedure

1. Sampling Rap Stockpile(s)

The first step in the mix design process is the determination of the properties of the constituent ingredients which will contribute to the final mixture. It is imperative that all test results come from

FIGURE 1


SAMPLING RAP STOCKPILE(S)
DETERMINE RAP PROPERTIES
- EXTRACTION GRADATION
- ASPHALT CONTENT
- PEN. OF RECOVERED AC
NEW AGGREGATE GRADATION
SELECT BLEND PERCENTAGE
DOES NOT MEET SPECIFICATION
DETERMINE COMBINED AGGREGATE GRADATION
DETERMINE TOTAL ASPHALT DEMAND (AMOUNT/%)
PENETRATION IS NOT WITHIN ALLOWABLE RANGE OR AC GRADE IS NOT AVAILABLE
DETERMINE AMOUNT/% OF NEW ASPHALT REQUIRED
DETERMINE COMBINED ASPHALT PENETRATION OR SELECT NEW ASPHALT GRADE
DETERMINE JMF
DETERMINE DRAW WEIGHTS/RATES

samples which accurately represent the stockpiles from which they were taken. Sampling procedures are extremely critical when dealing with RAP due to the wide diversity of sources from which the RAP may be obtained.

Regardless of the sampling plan utilized, it shall consist of a minimum of six (6) samples with each sample being at least 3,000 grams to insure that sufficient material is available to perform the tests listed in the next step.

2. Determine RAP Properties

The test sample shall reflect the material which will be introduced into the mixing unit. Therefore, if the sample is taken from the stockpile, the sample must be processed to remove all plus 2 inch materials.

In addition, any moisture in the RAP sample must be removed before testing can proceed (heating in a 225-250°F oven overnight should suffice). The prepared dry sample shall be tested as follows:

a) Extraction Gradation and Asphalt Content. Each sample shall be separated into its constituent components and the asphalt content determined by the method described in Materials Method 5. Extracting RAP will likely require more time than normal plant mix samples (6-8 hours is not unusual) and the procedure may be facilitated by using new rather than reclaimed solvent. The extracted asphalt/solvent solution, from each sample, shall be retained for further testing as described below.

The extracted aggregate shall be tested for gradation according to Materials Method 5 utilizing screen sizes listed in Table 401-1.

b) Penetration of Recovered Asphalt Cement. The asphalt cement shall be recovered from the above mentioned asphalt/solvent solution by the Abson Method described in ASTM D-1856. The Abson recovered asphalt cement, from each sample, shall then be tested for penetration at 77°F in accordance with ASTM D-5.

3. New Aggregate Gradation

The gradation of any new aggregates to be used in the recycled mixture should be readily available from hot bin testing at batch plants or stockpile gradation testing at drum mix plants. However, if aggregate sources change or plant modifications occur, additional sampling and testing shall be carried out to establish gradation values which the plant is capable of producing under normal operating conditions.

4. Select Blend Percentage

Once the gradations of the RAP and hot bins have been established and verified, it is possible to determine the RAP/new aggregate blend percentages to meet specification requirements. However, other factors must be considered when selecting blend percentages in addition to the RAP and new aggregate gradations.

One factor is the type of plant through which the recycled mix will be produced.

Past experience indicates that, under ideal conditions, a 50% RAP/50% new aggregate (50/50) blend is the maximum possible with a batch plant while a 70/30 blend is the maximum possible for a drum mixer. Because RAP material is usually added to the mixing unit at ambient temperature separately from the new aggregates, the combined RAP/new aggregate must be brought to the proper temperature by superheating the new aggregate portion to higher than normal levels (heat transfer method) and as the RAP percentage increases the new aggregate portion temperature must be increased accordingly. However, aggregate temperature can only be increased to a certain level before damage occurs in the dryer,

screens, pugmill, drum or dust collection system (particularly baghouses). Detrimental affects may also occur in the asphalt cements at a high temperature level. This level is generally considered to be in the 500-550°F range. Once the plant type has been decided upon, the most important factor which will influence the blend percentage is the moisture content in the RAP stockpile (See TABLE 2).

TABLE 2

ALLOWABLE RAP BLENDING PERCENTAGES*

RAP MOISTURE CONTENT (%)	MAXIMUM RAP (%) (BATCH PLANT)	(DRUM MIXER)
0.0 - 0.9	50	70
1.0 - 1.9	45	50
2.0 - 2.9	40	45
3.0 - 3.9	35	40
4.0 - 4.9	30	35
5.0 - 5.9	25	30
6.0 and over	20	25

*From Hot Mix Asphalt Concrete Pavement Recycle Specification.

Since the temperature of the new aggregate can be elevated only to a maximum level, any moisture present in the RAP portion must be driven off by some of the heat from the new aggregate thus reducing the amount of heat available to bring the RAP/new aggregate combination to the proper temperature.

With the limitations described above, normal operating conditions indicate practical blend percentages of 20-40% for batch plants and 30-50% for drum mix plants without resorting to protection of RAP stockpiles or reduction of normal production capacity.

Another factor to be considered is the grade of asphalt cement available to the Producer for restoring the resultant reclaimed/new asphalt combination to the proper penetration range. This factor usually determines the allowable RAP/new aggregate blend percentages.

If the new asphalt cement grade is not known, a RAP/new aggregate blend percentage must be selected based on the factors listed above, before continuing with Step 5.

If the new asphalt cement grade is known, then the RAP/new aggregate blend percentage may be calculated as described in a).

a) Using the Asphalt Blending Nomograph, BR 169, plot the average reclaimed AC penetration, from Step 2, on the left-hand vertical axis as shown in Figure 2 (Point 1). Next, plot the penetration of the new AC on the right-hand vertical axis (Point 2). With a straight line connect Points 1 and 2. On this line, plot the lower and upper allowable combined penetrations (see recycle specification) Points 3 and 4. By drawing a vertical line from Points 3 and 4 to the lower axis, the maximum and minimum allowable asphalt blend percentages (P_N/P_T X 100) are found.

   Using Equation 1 the maximum and minimum allowable RAP blend percentages can be calculated.

EQUATION 1:

$$\text{RAP Blend \%} = \frac{(1 - P_N/P_T)\, P_T}{P_R}$$

WHERE:

P_T = Percent of total mix-asphalt content based on total mix weight.

P_R = Percent of asphalt in the RAP material.

FIGURE 2

BR 169 (11/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ASPHALT BLENDING NOMOGRAPH

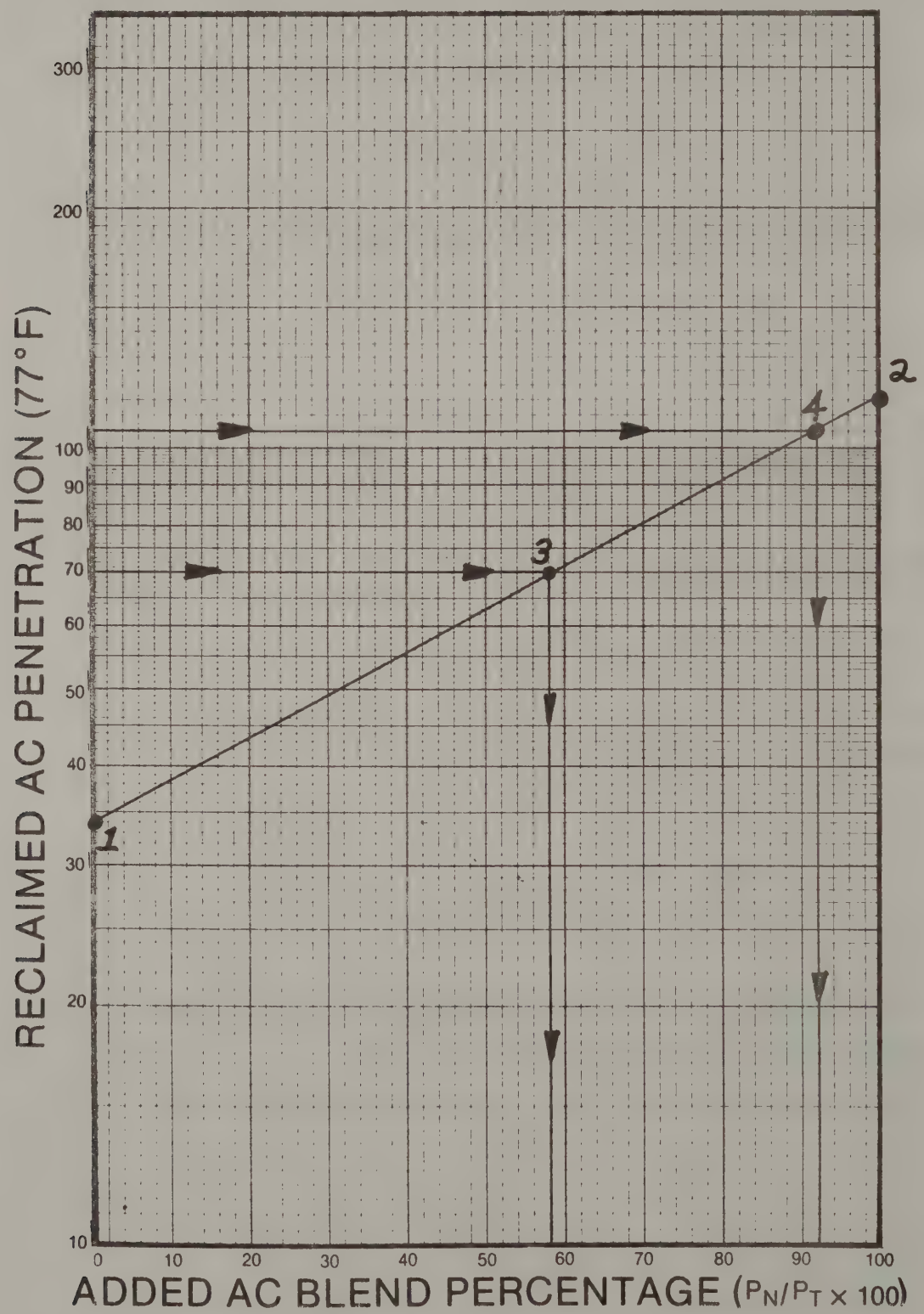
REGION 13 RAP STOCKPILE #3 MIX TYPE ------

PLANT XY PAVING INC. RAP BLEND % ------

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS DATE 8/20/84

ADDED AC GRADE AC-10 ADDED AC PEN. 115 TOTAL AC CONTENT 5.5



After determining the maximum and minimum blend percentages, the desired blend percentage or percentages can be selected by the producer.

5. Determine Combined Aggregate Gradations

Once the Producer has selected the blend percentage(s) and having already determined the gradation of his RAP stockpiles from Step 2 and the hot bin gradation from Step 3, he can now determine what the resultant combined gradation will be by simple mathematical computations or procedures as listed in the Asphalt Institute MS-2, Materials Method 5 and other references.

If the resultant gradation meets the specified mix requirements, the Producer should proceed to the next step. If, however, gradation requirements are not met, corrective measures are necessary and may include varying the blend percentage or the hot bin draw percentages among others.

6. Determine Total Asphalt Demand

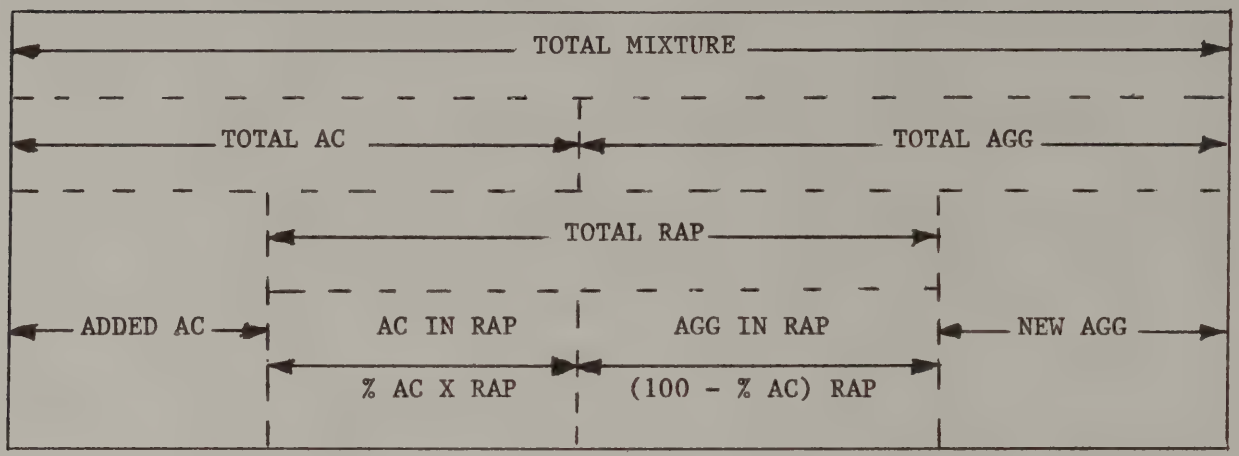
When mix design procedures such as Marshall are not adaptable, past experience must be utilized to determine the asphalt content of the mix type in question. Normally, this value would be the same whether the mix is made with 100% new aggregate or contains some RAP material (e.g. 5.5% for dense binder, etc.).

7. Percent of New Asphalt Required

As can be seen from Figure 3, the asphalt cement in the final recycled mixture is the sum of that which will be contributed by the RAP portion and the amount which must be added at the time of batching.

FIGURE 3

RECYCLED MIXTURE DIAGRAM



The added AC amount can be obtained by the following equation:

EQUATION 2:

$$P_N = P_T - \left[\frac{(100\% - P_T)}{\left(\frac{100\% - P_R}{100\%}\right) + \left(\frac{100\% - RAP\%}{RAP\%}\right)} \times \frac{P_R}{100\%} \right]$$

WHERE:

P_N = Percent of new asphalt required based on total mix weight.

P_T = Percent of total mix asphalt content based on total mix weight.

P_R = Percent of asphalt in the RAP material.

RAP% = RAP blend percentage selected.

If the new asphalt cement grade is known, follow Step 8. If the new AC grade is not known, follow Step 9.

8. Determine Combined Asphalt Penetration

The use of the asphalt blending nomograph BR 169, shown in Figure 4 will yield the actual combined penetration. First the average penetration of the reclaimed AC from Step 2 is plotted on the left-hand vertical axis as Point 1. Next, plot the penetration of the new AC on the right-hand vertical axis (Point 2). Now draw a straight line between Points 1 and 2. Noting that the added AC content blend percentage is determined by dividing the added AC content (Step 7) by the total asphalt content (Step 6) times 100 (i.e., P_N/P_T X 100), plot this value on the lower horizontal axis Point 3. Draw a vertical line from Point 3 to the line between Points 1 and 2. The intersection of these lines, Point 4 is the actual combined penetration for a given RAP/new aggregate blend percentage.

If the combined penetration is not within the allowable range (see recycle specification) a new RAP/new aggregate blend percentage must be selected and the design procedure repeated from Step 4. Several RAP blend percentages may be plotted on the same nomograph. Continue with Section B.

9. Select New Asphalt Grade

The use of the asphalt blending nomograph, BR 169, shown in Figure 5 will yield the new asphalt grade required to produce a reclaimed/added asphalt combination having a penetration value meeting specification requirements. First the average penetration of the reclaimed AC from Step 2 is plotted on the left-hand vertical axis as Point 1. Next, the point representing the added AC content blend percentage and the combined penetration is plotted as Point 2. The combined penetration value chosen in this example is 80 which is within the specification range of 70-105. Note that the added AC content blend percentage is determined by dividing the added AC content by the total asphalt content times 100 (i.e., P_N/P_T X 100%). A straight line can now be drawn from Point 1 through Point 2 and extended to the right-hand

FIGURE 4

BR 169 (11/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ASPHALT BLENDING NOMOGRAPH

REGION 13 RAP STOCKPILE #3 MIX TYPE ------

PLANT XY PAVING INC. RAP BLEND % -----

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS DATE 8/20/84

ADDED AC GRADE AC-10 ADDED AC PEN. 115 TOTAL AC CONTENT 5.5

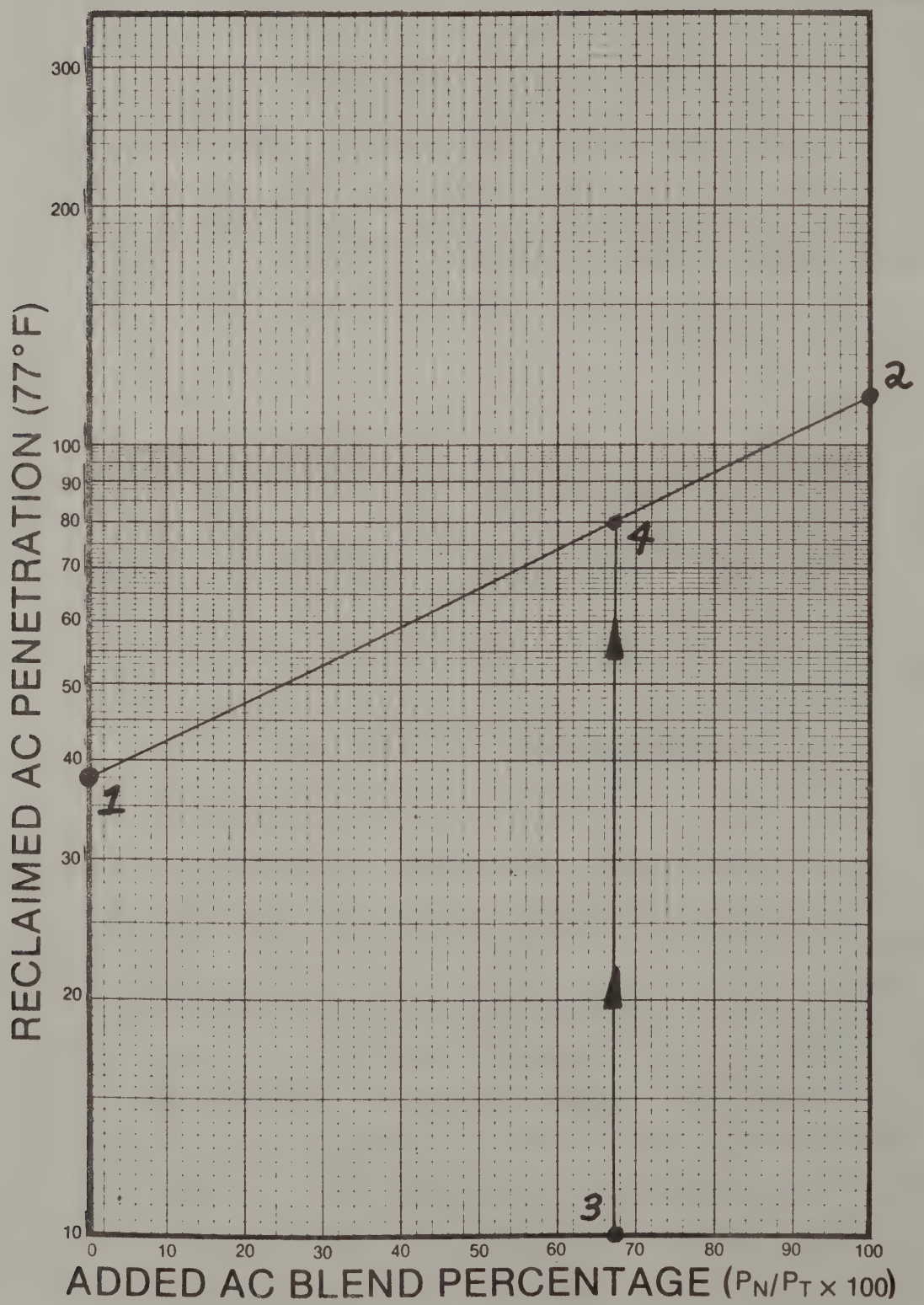


FIGURE 5

BR 169 (11/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ASPHALT BLENDING NOMOGRAPH

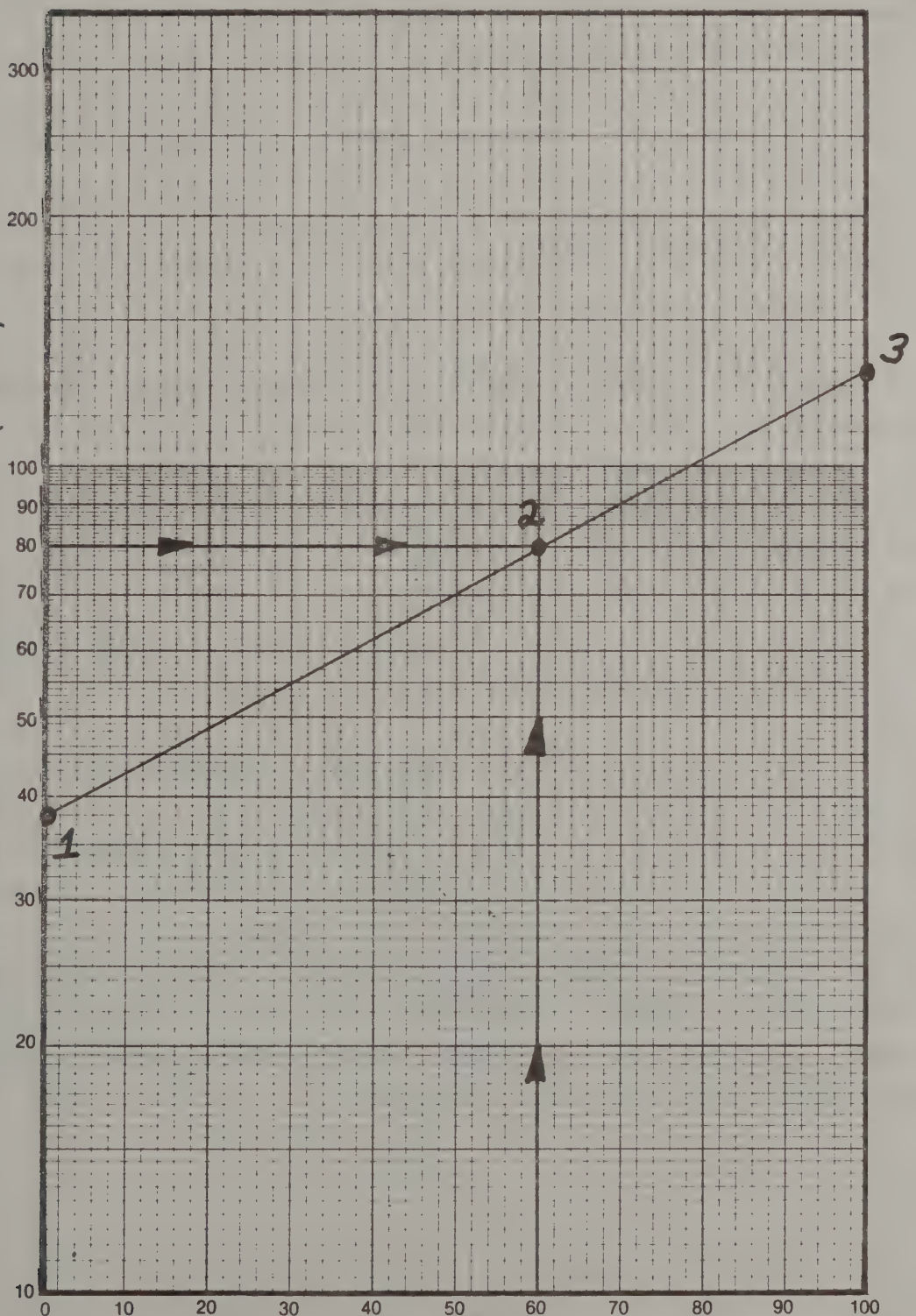
REGION 13 RAP STOCKPILE #3 MIX TYPE -----

PLANT XY PAVING INC. RAP BLEND % --------

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS DATE 8/20/84

ADDED AC GRADE AC-10 ADDED AC PEN. 115 TOTAL AC CONTENT 5.5



ADDED AC PENETRATION (77°F)

vertical axis. This point (#3) indicates the added asphalt cement penetration necessary to satisfy the design criteria. If the point falling on the right-hand vertical axis is not within the penetration range covered by the normally available Asphalt Cement Grades or the required Grade is not available to the Producer, a different RAP blend percentage must be selected that will produce an acceptable mix design under actual conditions and materials availability. This may be accomplished by reentering the design procedure at Step 4 and proceeding forward by trial and error.

B. Job Mix Formula

Job mix formulas shall be submitted in the same manner as for total new aggregate mixes except that for recycled mixes the following information shall be included:

a) A summary of the RAP stockpile test results showing for each sample:
   1. Gradation and asphalt content.
   2. Penetration of the recovered AC.
b) BR 146, Recycle Mix Design Worksheet.
c) BR 169, Asphalt Blending Nomograph
d) The appropriate Department form for the mixture type (e.g. BR 153 for Recycle Type 3, Dense Binder).

Recycle JMF's shall be submitted for RAP percentages in 5% increments (e.g. 25/75, 30/70, etc.). Several RAP blend percentages may be plotted on one nomograph for a given mix type providing the new AC remains the same. Once approved, a recycle JMF shall be strictly followed and no deviation in the RAP percentage will be allowed. Therefore, if the Producer is unsure as to his final mix or desires the flexibility of a range of RAP percentages, he should submit a JMF for each anticipated RAP blend percentage (e.g. 25/75, 30/70, 35/65). In this case, one summary of RAP stockpile test results will be sufficient to cover all JMF's submitted.

APPENDIX 1

EXAMPLE 1

This example will assume that the new AC grade is known. Assume that it is desired to produce a recycled mix meeting the requirements for Type 3 Dense Binder through a three ton batch plant. Assume furthermore, that the sampling plan for the RAP stockpile required six samples, the test results of which are listed in TABLE 1, the historical hot bin gradation of the new aggregate is available, and an AC 10 with a penetration of 115 will be used.

TABLE 1

RAP STOCKPILE SAMPLE TEST VALUES

SIEVE SIZE	EXTRACTED GRADATIONS (% PASSING) Sample #1	Sample #2	Sample #3	Sample #4	Sample #5	Sample #6	Range	Average
2"								-
1 1/2"								100
1"			ACTUAL					100
1/2"			TEST					93.9
1/4"			RESULTS					73.3
1/8"			OF EACH					45.1
20			SAMPLE					21.9
40								14.5
80								8.2
200								4.9
AC Content (%)								6.2
Penetration								38

In addition, the Producer has decided not to protect his RAP stockpiles from the weather and, therefore, can reasonably assume 4% moisture content at the time of batching.

SELECT RAP BLEND PERCENTAGE

Using the asphalt blending nomograph BR 169 in Figure 6, the average penetration of the recovered AC from the RAP stockpile samples (38 from TABLE 1) is plotted on the left-hand vertical axis (Point 1). Next plot the new AC penetration (115) on the right-hand vertical axis (Point 2). Now, with a straight line, connect Points 1 and 2. On this line plot the lower and upper allowable combined penetrations Point 3 and 4 respectively (see recycle specification). In this example 70 and 105 are used. By drawing vertical lines downward from Points 3 and 4 the minimum and maximum allowable asphalt blend percentages (P_N/P_T X 100) are found (55.0 and 92.0 respectively). Using Equation 1, the maximum and minimum allowable RAP blend percentages can be calculated.

EQUATION 1:

$$\text{RAP Blend \%} = \frac{(1 - P_N/P_T)\, P_T}{P_R}$$

Maximum

$$\text{RAP blend \%} = \frac{(1 - .55)5.5}{6.2}$$

RAP blend % = 40%

Minimum

$$\text{RAP blend \%} = \frac{(1 - .92)5.5}{6.2}$$

RAP blend % = 7.0%

This indicates that RAP blend percentages between 10% and 40% can be used.

Referring to Table 2 on page 6, at 4% moisture the maximum allowable RAP blend percentage for a batch plant is 30%.

In this example, it has been decided to design for the maximum allowable RAP percentage of 30%. However, designs could be developed for as many RAP blend percentages between 10 and 30% as desired.

BR 169 (11/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ASPHALT BLENDING NOMOGRAPH

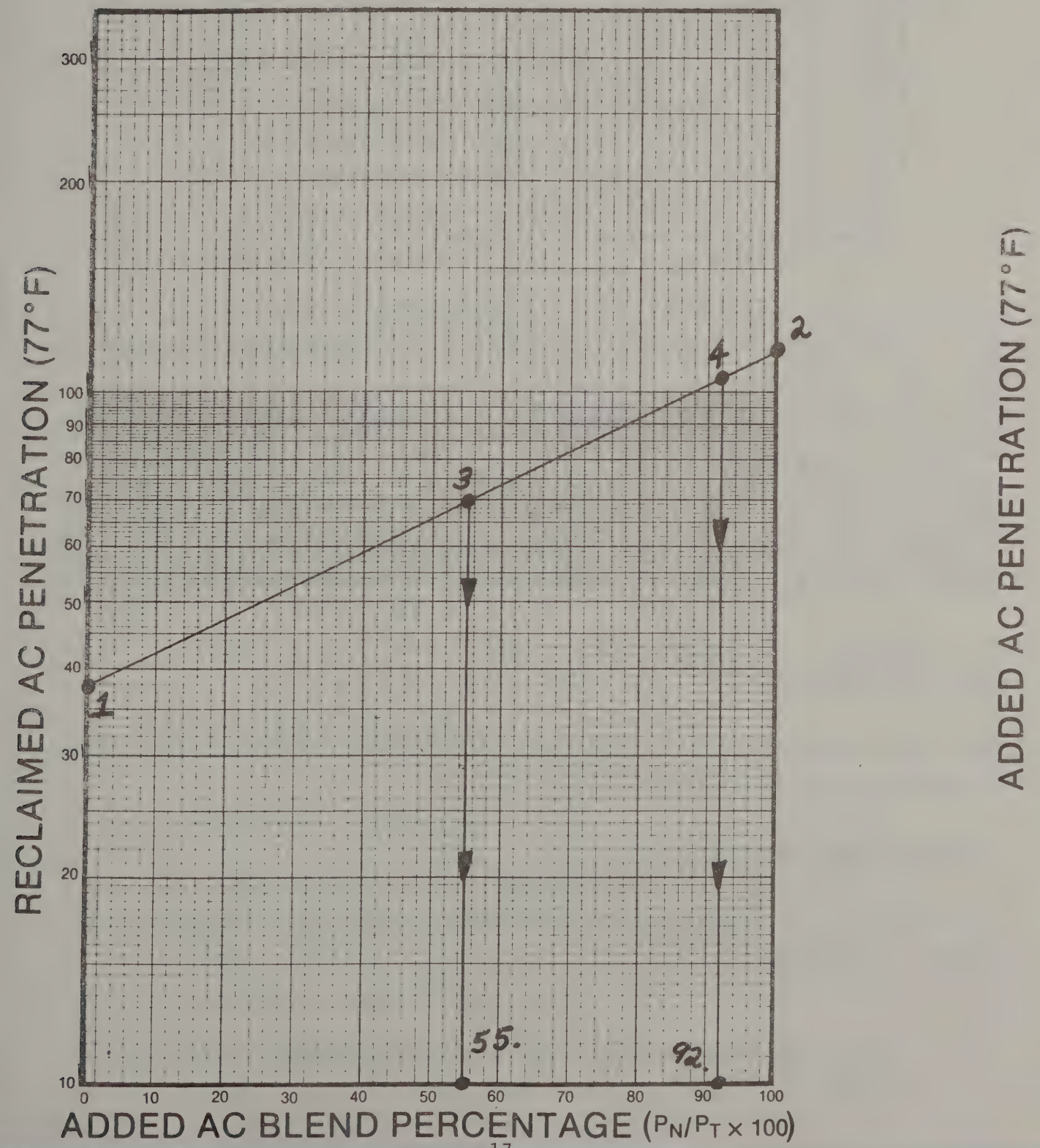
REGION 13 RAP STOCKPILE #3 MIX TYPE BINDER(Dense)

PLANT XY PAVING INC. RAP BLEND % ----

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS DATE 8/20/84

ADDED AC GRADE AC-10 ADDED AC PEN. 115 TOTAL AC CONTENT 5.5



COMBINED AGGREGATE GRADATION

INDIVIDUAL AGGREGATE/RAP GRADATIONS

Sieve Sizes	No. 2* % Pass.	No. 1* % Pass.	No. 1A* % Pass.	Fines* % Pass.	EXTRACTED RAP** % Pass.
2"					
1 1/2"	100	100	100	100	100
1"	95.4	100	100	100	100
1/2"	2.9	83.1	100	100	93.9
1/4"	0.5	3.0	97.7	100	73.3
1/8"	0.4	0.9	7.6	99.0	45.1
20		0.5	0.3	60.5	21.9
40		0.5	0.3	32.3	14.5
80		0.5	0.3	10.0	8.2
200		0.3	0.2	3.7	4.9
PAN					

*Based on Previous testing of the plants hot bin production.
**Refer to TABLE 1.

COMBINED GRADATION

BIN	% BATCHED	% Passing Sieve 2"	1 1/2"	1"	1/2"	1/4"	1/8"	20	40	80	200
2	10		10.0	9.5	0.3	0.1	0.1	0.1	0.1	0.1	0.1
1	20		20.0	20.0	16.6	0.6	0.2	0.1	0.1	0.1	0.1
1A											
	70% New Agg.										
FINES	40		40.0	40.0	40.0	40.0	39.6	24.2	12.9	4.0	1.5
RAP	30		30.0	30.0	28.2	22.0	13.5	6.6	4.4	2.5	1.5
TOTAL			100	99.5	85.1	62.7	53.4	31.0	17.5	6.7	3.2
JOB MIX LIMITS			100	95-100	79-90	56-70	46-60	24-38	11-25	4-11	2-5
GENERAL LIMITS			100	95-100	70-90	48-74	32-62	15-39	8-27	4-16	2-8

TOTAL ASPHALT DEMAND

The asphalt content for dense binder must fall between 4.5 and 6.5% (specification range) and is normally set at 5.5%.

PERCENT OF NEW ASPHALT REQUIRED

Using BR 146, the Recycle Mix Design Worksheet (Figure 7) the percentage of new asphalt required can be calculated.

BR-146 (12/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

RECYCLE MIX DESIGN WORKSHEET

REGION 13 RAP STOCKPILE #3 MIX TYPE BINDER(Dense)

PLANT XY PAVING INC. RAP BLEND % 30

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS ON 8/20/84

I. DETERMINATION OF (RAP) PROPERTIES:

A. NUMBER OF TESTS (ATTACH TEST RESULTS) 6

B. AVERAGE ASPHALT CONTENT (P_R) 6.2

C. AVERAGE PENETRATION 38

D. (RAP) GRADATION - (SEE TEST RESULTS)

II. TOTAL ASPHALT DEMAND (P_T): 5.5

III. PERCENT NEW ASPHALT REQUIRED:

USING FORMULA -

$$P_N = P_T - \left[\left(\frac{100\% - P_T}{\frac{100\% - P_R}{100\%} + \frac{100\% - (RAP)\ \%}{(RAP)\ \%}} \right) \frac{P_R}{100\%} \right]$$

WHERE:

P_N = Percent New Asphalt Required

P_T = Percent Total Asphalt Demand

P_R = Percent Asphalt in (RAP)

$$P_N = 5.5 - \left[\left(\frac{100\% - 5.5}{\frac{100\% - 6.2}{100\%} + \frac{100\% - 30}{30}} \right) \frac{6.2}{100\%} \right]$$

P_N = 3.71 %

NEW A.C. PERCENTAGE: 100 (P_N/P_T) = 67.5

IV. SELECTION OF NEW ASPHALT:

GRADE AC-10 PENETRATION 115

V. COMBINED FINAL A.C. PENETRATION: 80

(Attach Asphalt Blending Nomograph)

VI. NEW GRADATION AND BLEND PERCENTAGES:

(Attach Combined Gradation and Job Mix Formula Sheets)

DETERMINE COMBINED ASPHALT PENETRATION

Using the asphalt blending nomograph BR 169 in Figure 8, the average penetration of the recovered AC from the RAP stockpile samples (38 from TABLE 2) is plotted on the left-hand vertical axis (Point 1). Next, the penetration of the new AC 115, is plotted on the right-hand vertical axis (Point 2). Points 1 and 2 are now connected with a straight line. Next the percentage of added asphalt cement based on the total asphalt volume (P_N/P_T X 100 = 3.71%/5.5% X 100 = 67.5%) is plotted (Point 3). Draw a vertical line from Point 3 to the line between Points 1 and 2. The intersection of these two lines (Point 4) gives the actual combined penetration of 80 for a RAP blend percentage of 30%. The penetration of 80 is well within the allowable specification range.

DETERMINATION OF DRAW WEIGHTS

As can be seen from Figure 9, the recycled mixture consists of 3.71% added AC 10, 28.89% RAP and 67.40% new aggregate. For a normal 3 ton (6,000 lb.) batch this would result in draw weights of 223#, 1733# and 4044# respectively. The RAP draw weight is composed of 107# of asphalt and 1626# of aggregate. The sum of the AC in the RAP and the AC 10 added (107# + 223#) equals 330# which is the desired total AC content (5.5% of 6,000#). With this information and the draw percentages of the new aggregate hot bins from page 18, the individual material draw weights can be established assuming the following weighing sequence:

TABLE 3

	MATERIAL			Draw Weights (6,000# batch) Individual	Cumulative
4044	Fines	(40%)		2311	2311
4044	#1	(20%)		1155	3466
4044	#2	(10%)	5777	578	4044
1733	RAP	(30%)		1733	5777
	AC 10			223	6000

BR 169 (11/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ASPHALT BLENDING NOMOGRAPH

REGION 13 RAP STOCKPILE #3 MIX TYPE BINDER(Dense)

PLANT XY PAVING INC. RAP BLEND % 30

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS DATE 8/20/84

ADDED AC GRADE AC-10 ADDED AC PEN. 115 TOTAL AC CONTENT 5.5

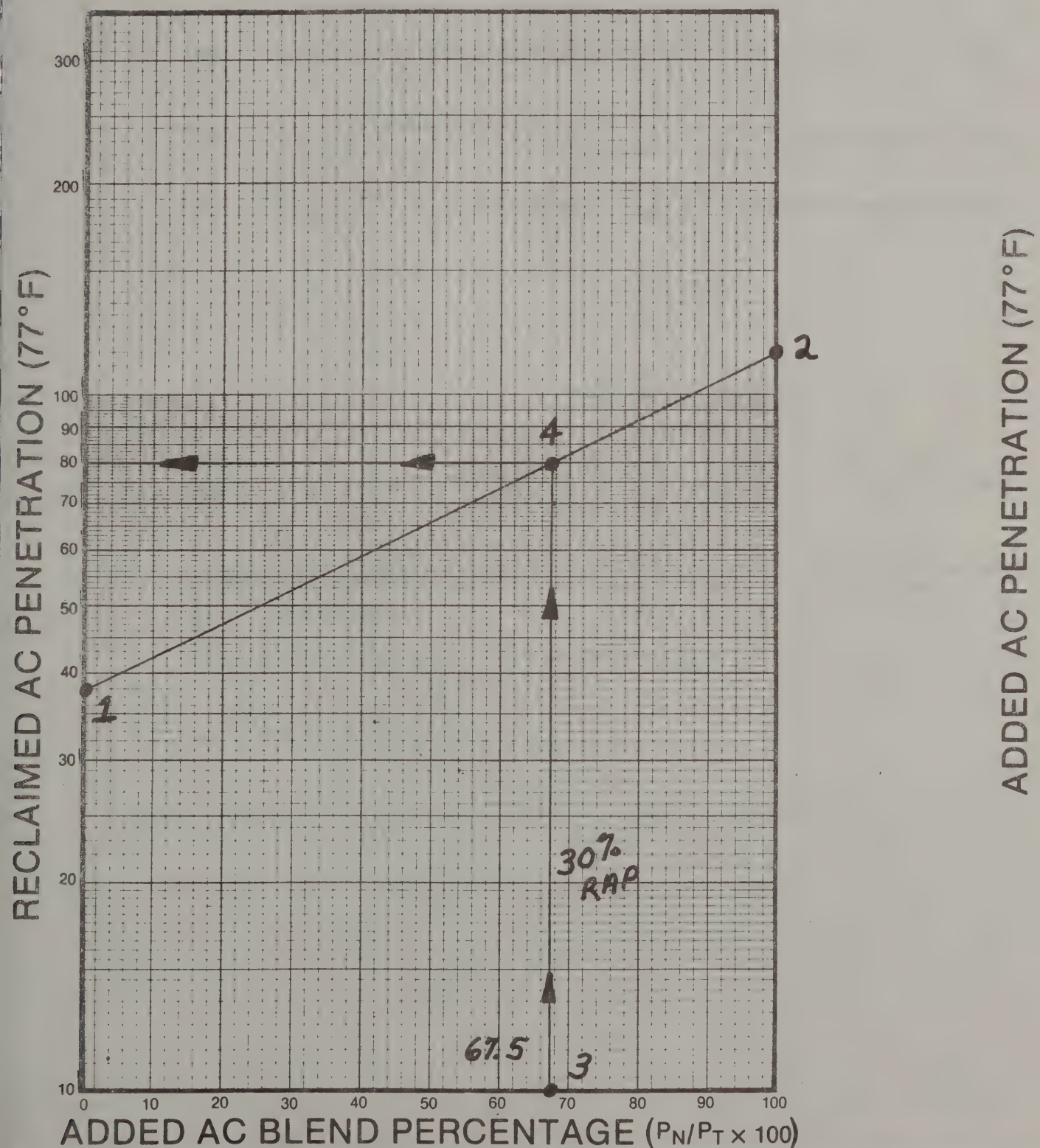
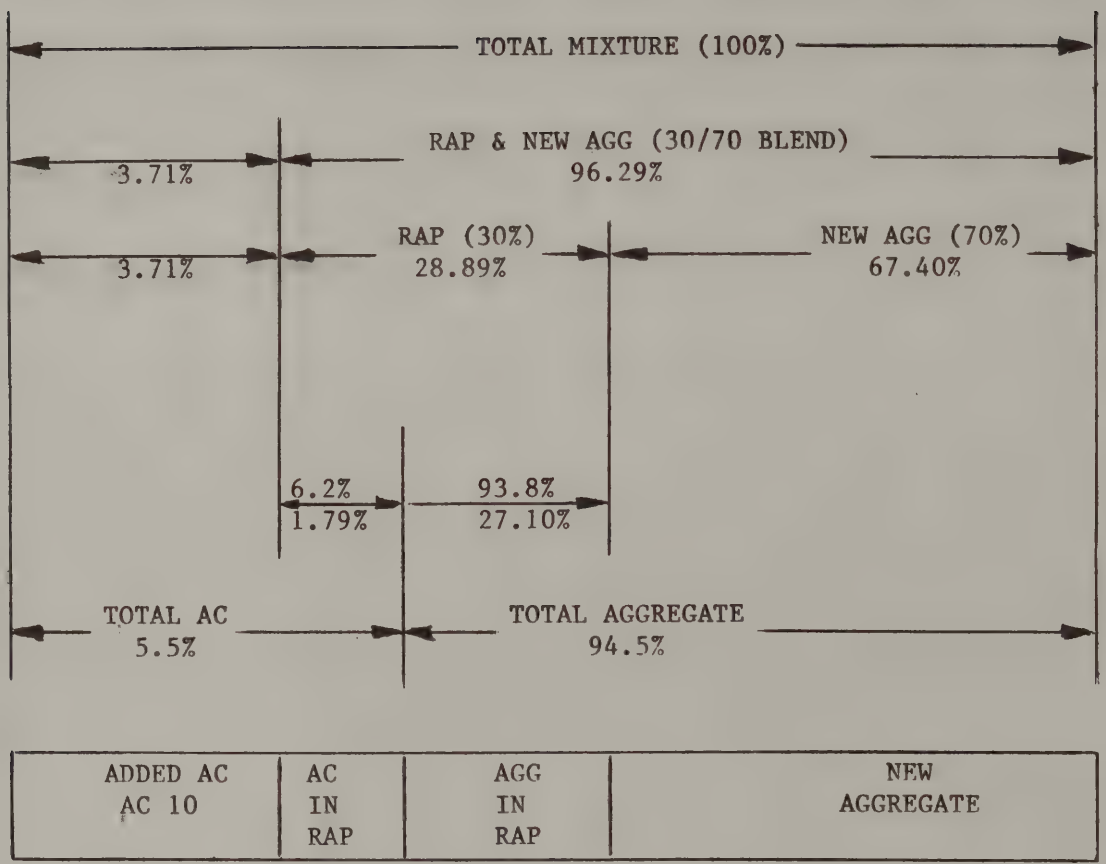


FIGURE 9

RECYCLED MIXTURE SCHEMATIC



However, the above draw weights are good only when all materials are oven dry at the time of batching. When the RAP material entering the pugmill has any moisture included, the RAP draw weight must be increased to compenstate for the moisture content present as illustrated in the following table:

TABLE 4

RAP draw weight adjusted for moisture content

% Moisture	RAP Draw Weight (Lbs.)
0.0	1733
0.5	1742
1.0	1750
1.5	1759
2.0	1768
2.5	1776
3.0	1785
3.5	1794
4.0	1802
4.5	1810
5.0	1820

JMF SUBMISSION

The JMF package submitted by the Producer to the Department for review and approval shall consist of the following:

a) Test results of the RAP stockpile samples as illustrated in TABLE 1. (Note: When the Producer submits JMF's for varying amounts of RAP blend at one time, only one set of this data will be required.)

b) Completed BR 146, Recycle Mix Design Worksheet as illustrated in Figure 7

c) BR 169, Asphalt Blending Nomograph as illustrated in Figure 8

d) Completed BR 153 with all pertinent information as illustrated in Figure 10.

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

JOB MIX FORMULA

Recycle Type 3, Binder (Dense)

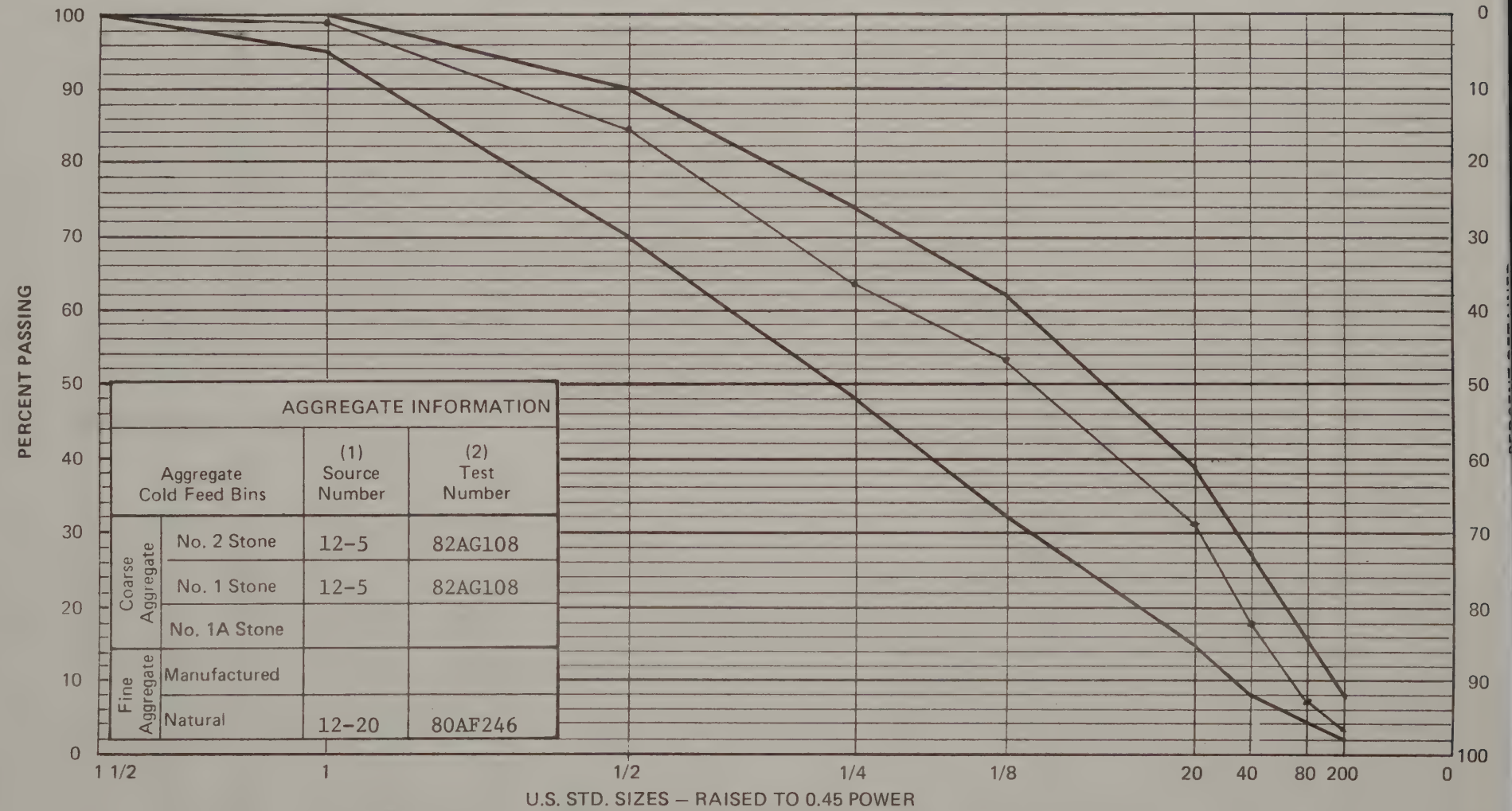
Region 13 RAP Stockpile #3 JMF No. 1

Plant XY PAVING INC. Pugmills 1

Plant Location BLACKVILLE, N.Y.

Submitted By JOHN PETERS Title Q.C. TECH

(Submission instructions on back)



AGGREGATE INFORMATION

Aggregate Cold Feed Bins		(1) Source Number	(2) Test Number
Coarse Aggregate	No. 2 Stone	12-5	82AG108
	No. 1 Stone	12-5	82AG108
	No. 1A Stone		
Fine Aggregate	Manufactured		
	Natural	12-20	80AF246

Sieve Size		2"	1 1/2"	1"	1/2"	1/4"	1/8"	No. 20	No. 40	No. 80	No. 200	Asphalt Content (Percent)
% Passing	1. General Limits		100	95-100	70-90	48-74	32-62	15-39	8-27	4-16	2-8	4.5-6.5
	2. JMF Range		100	95-100	79-90	56-70	46-60	24-38	11-25	4-11	2-5	
	3. Target Value		100	99	85	63	53	31	18	7	3	5.5(total)

Asphalt Grade Added
AC 10

Added Asphalt Content: 3.71 % RAP/New Aggregate Blend: 30/70

Approved Date

BR 153 (11/83)

APPENDIX 2

EXAMPLE 2

For this example, we will assume that the new AC grade is not known. Assume that it is desired to produce a recycled mix meeting the requirements for Type 3 Dense Binder through a 300 TPH drum mixer. Assume furthermore, that the sampling plan for the RAP stockpile required six samples, the test results of which are listed in TABLE 1 and the historical gradation of the new aggregate is available. In addition, the Producer has decided not to protect his RAP stockpiles from the

TABLE 1

RAP STOCKPILE SAMPLE TEST VALUES

SIEVE SIZE	EXTRACTED GRADATIONS (% PASSING) Sample #1	Sample #2	Sample #3	Sample #4	Sample #5	Sample #6	Range	Average
2"								-
1 1/2"								100
1"								100
1/2"			ACTUAL					93.9
1/4"			TEST					73.3
1/8"			RESULTS					45.1
20			OF EACH					21.9
40			SAMPLE					14.5
80								8.2
200								4.9
AC Content (%)								6.2
Penetration								38

weather and, therefore, can reasonably assume 4% moisture content at the time of mixing. Referring to TABLE 2 on page 6, it can be seen that a maximum of 35% RAP is possible given a moisture content of 4%.

In this example it has been decided to design for a 30% RAP/new aggregate blend.

COMBINED AGGREGATE GRADATION

INDIVIDUAL AGGREGATE/RAP GRADATIONS

Sieve Sizes	No. 2* % Pass.	No. 1* % Pass.	No. 1A* % Pass.	Fines* % Pass.	EXTRACTED RAP** % Pass.
2"					
1 1/2"	100	100	100	100	100
1"	95.4	100	100	100	100
1/2"	2.9	83.1	100	100	93.9
1/4"	0.5	3.0	97.7	100	73.3
1/8"	0.4	0.9	7.6	99.0	45.1
20		0.5	0.3	60.5	21.9
40		0.5	0.3	32.3	14.5
80		0.5	0.3	10.0	8.2
200		0.3	0.2	3.7	4.9
PAN					

*Based on Previous testing of the plants hot bin production.
**Refer to TABLE 1.

COMBINED GRADATION

BIN	% BATCHED	% Passing Sieve									
		2"	1 1/2"	1"	1/2"	1/4"	1/8"	20	40	80	200
2	10		10.0	9.5	0.3	0.1	0.1	0.1	0.1	0.1	0.1
1	20		20.0	20.0	16.6	0.6	0.2	0.1	0.1	0.1	0.1
1A											
	70%	New Agg.									
FINES	40		40.0	40.0	40.0	40.0	39.6	24.2	12.9	4.0	1.5
RAP	30		30.0	30.0	28.2	22.0	13.5	6.6	4.4	2.5	1.5
TOTAL			100	99.5	85.1	62.7	53.4	31.0	17.5	6.7	3.2
JOB MIX LIMITS			100	95-100	79-90	56-70	46-60	24-38	11-25	4-11	2-5
GENERAL LIMITS			100	95-100	70-90	48-74	32-62	15-39	8-27	4-16	2-8

TOTAL ASPHALT DEMAND

The asphalt content for dense binder must fall between 4.5 and 6.5% (specification range) and is normally set at 5.5%

PERCENT OF NEW ASPHALT REQUIRED

Using BR 146, the Recycle Mix Design Worksheet (Figure 11), the percentage of new asphalt required can be calculated.

BR-146 (12/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

RECYCLE MIX DESIGN WORKSHEET

REGION 13 RAP STOCKPILE #3 MIX TYPE BINDER (Dense)

PLANT XY PAVING INC. RAP BLEND % 30

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS ON 8/20/84

I. DETERMINATION OF (RAP) PROPERTIES:

A. NUMBER OF TESTS (ATTACH TEST RESULTS) 6

B. AVERAGE ASPHALT CONTENT (P_R) 6.2

C. AVERAGE PENETRATION 38

D. (RAP) GRADATION - (SEE TEST RESULTS)

II. TOTAL ASPHALT DEMAND (P_T): 5.5

III. PERCENT NEW ASPHALT REQUIRED:

USING FORMULA -

$$P_N = P_T - \left[\left(\frac{100\% - P_T}{\frac{100\% - P_R}{100\%} + \frac{100\% - (RAP)\ \%}{(RAP)\ \%}} \right) \frac{P_R}{100\%} \right]$$

WHERE:

P_N = Percent New Asphalt Required

P_T = Percent Total Asphalt Demand

P_R = Percent Asphalt in (RAP)

$$P_N = 5.5 - \left[\left(\frac{100\% - 5.5}{\frac{100\% - 6.2}{100\%} + \frac{100\% - 30}{30}} \right) \frac{6.2}{100\%} \right]$$

P_N = 3.71 %

NEW A.C. PERCENTAGE: 100 (P_N/P_T) = 67.5

IV. SELECTION OF NEW ASPHALT:

GRADE AC-10 PENETRATION 115

V. COMBINED FINAL A.C. PENETRATION: 80

(Attach Asphalt Blending Nomograph)

VI. NEW GRADATION AND BLEND PERCENTAGES:

(Attach Combined Gradation and Job Mix Formula Sheets)

SELECT NEW ASPHALT GRADE

Using the asphalt blending nomograph BR 169 in Figure 12, the average penetration of the recovered AC from the RAP stockpile samples (38 from TABLE 1) is plotted on the left-hand vertical axis (Point 1). Next, the intersection point of the combined penetration (assume 80 - which is within the allowable specification range) and the percentage of added asphalt cement based on total asphalt volume (P_N/P_T X 100 = 3.71%/5.5% X 100 = 67.5%) is plotted (Point 2). A line drawn through these points intercepts the right-hand vertical axis (penetration of the new AC) at approximately 115, just outside of the allowable range for AC 20 but within that for AC 10.

It can also be seen that a line drawn through Points 1 and 3 (intersection of P_N/P_T = 67.5% and the minimum allowable value for the combined AC's) would permit the use of an AC 15 or AC 20 with a penetration equal to or greater than 93.

If the AC 20 normally available to the Producer has a penetration less than 93 and AC 10 is not available, the use of an AC 5 having a penetration less than 170 would result in a final penetration of less than the maximum allowable as indicated by the line drawn through Points 1 and 4 (the intersection of P_N/P_T = 67.5% and the maximum allowable penetration of the combined AC's).

If none of these alternatives produce acceptable values, the Producer would most likely have to reduce the RAP blend percentage to bring the penetration value within a range that can be achieved with the available material.

For this example an AC 10 will be used with a penetration of 115.

DETERMINATION OF DRAW WEIGHTS

As can be seen from Figure 13, this recycled mixture consists of 3.71% added AC 10, 28.89% RAP and 67.40% new aggregate. For the 300 TPH drum mixer in this example, the respective batching rates would be 11.1 TPH, 87 TPH and 202 TPH at full capacity.

BR 169 (11/83)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

ASPHALT BLENDING NOMOGRAPH

REGION 13 RAP STOCKPILE #3 MIX TYPE BINDER (Dense)

PLANT XY PAVING INC. RAP BLEND % 30

PLANT LOCATION BLACKVILLE, N.Y.

SUBMITTED BY JOHN PETERS DATE 8/20/84

ADDED AC GRADE AC-10 ADDED AC PEN. 115 TOTAL AC CONTENT 5.5

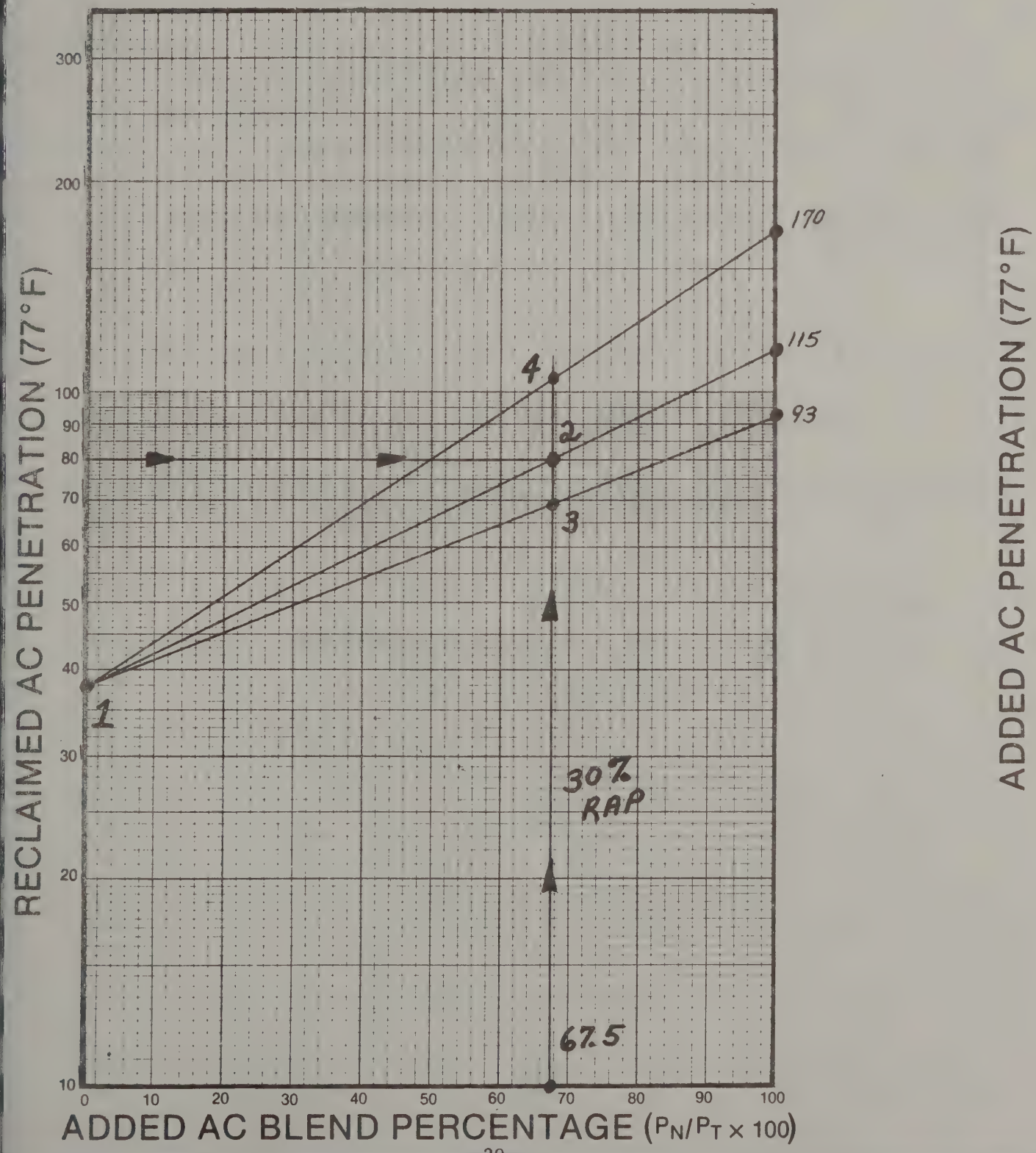
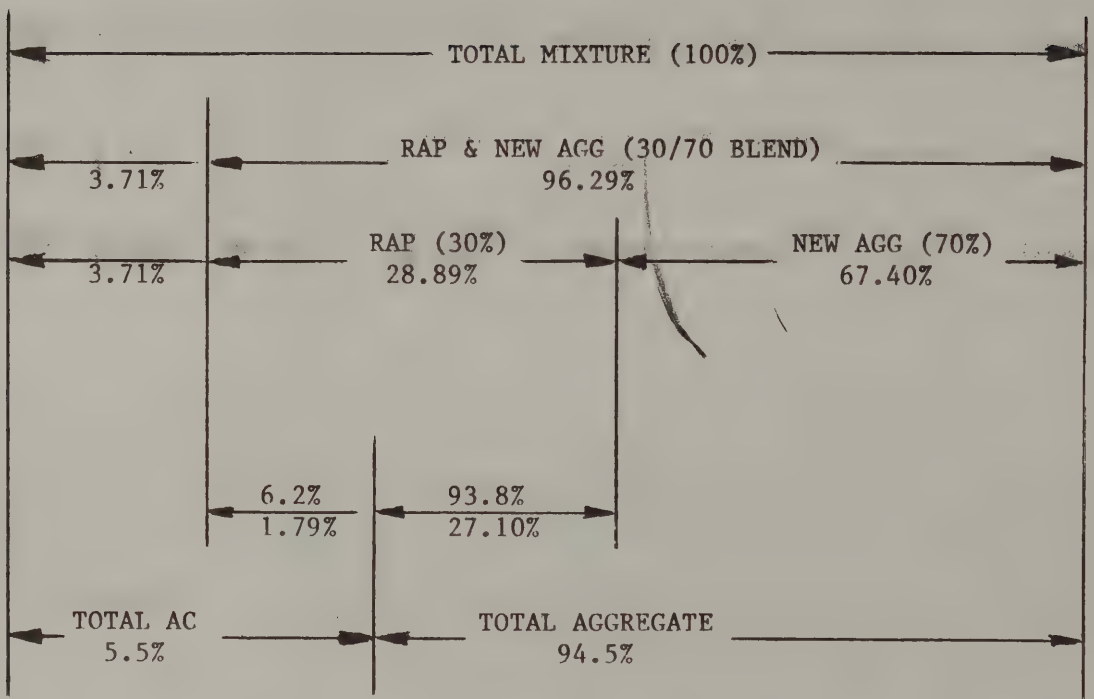


FIGURE 13

RECYCLED MIXTURE SCHEMATIC



ADDED AC AC 10	AC IN RAP	AGG IN RAP	NEW AGGREGATE

The RAP draw rate is comprised of 6.2% or 5.4 TPH of asphalt and 81 TPH of aggregate. The sum of AC in the RAP plus the added AC 10 (5.4 TPH + 11.1 TPH) equals 16.5 TPH which is the desired total AC content (5.5% of 300 TPH).

Unlike the situation in batch plants, the moisture included in the RAP is automatically compensated for by the plant equipment.

JMF SUBMISSION

The JMF package submitted by the Producer to the Department for review and approval should consist of the following:

a) Test results of the RAP stockpile samples as illustrated in TABLE 1 (Note: When the Producer submits JMF's for varying amounts of RAP blend at one time, only one set of this data will be required.)

b) Completed BR 146, Recycle Mix Design Worksheet as illustrated in Figure 11.

c) BR 169, Asphalt Blending Nomograph, as illustrated in Figure 12.

d) Completed BR 153 with all pertinent information as illustrated in Figure 14.

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

JOB MIX FORMULA

Recycle Type 3, Binder (Dense)

Region 13 RAP Stockpile #3 JMF No. 1

Plant XY PAVING INC. Pugmills 1

Plant Location BLACKVILLE, N.Y.

Submitted By JOHN PETERS Title Q.C. TECH

(Submission instructions on back)

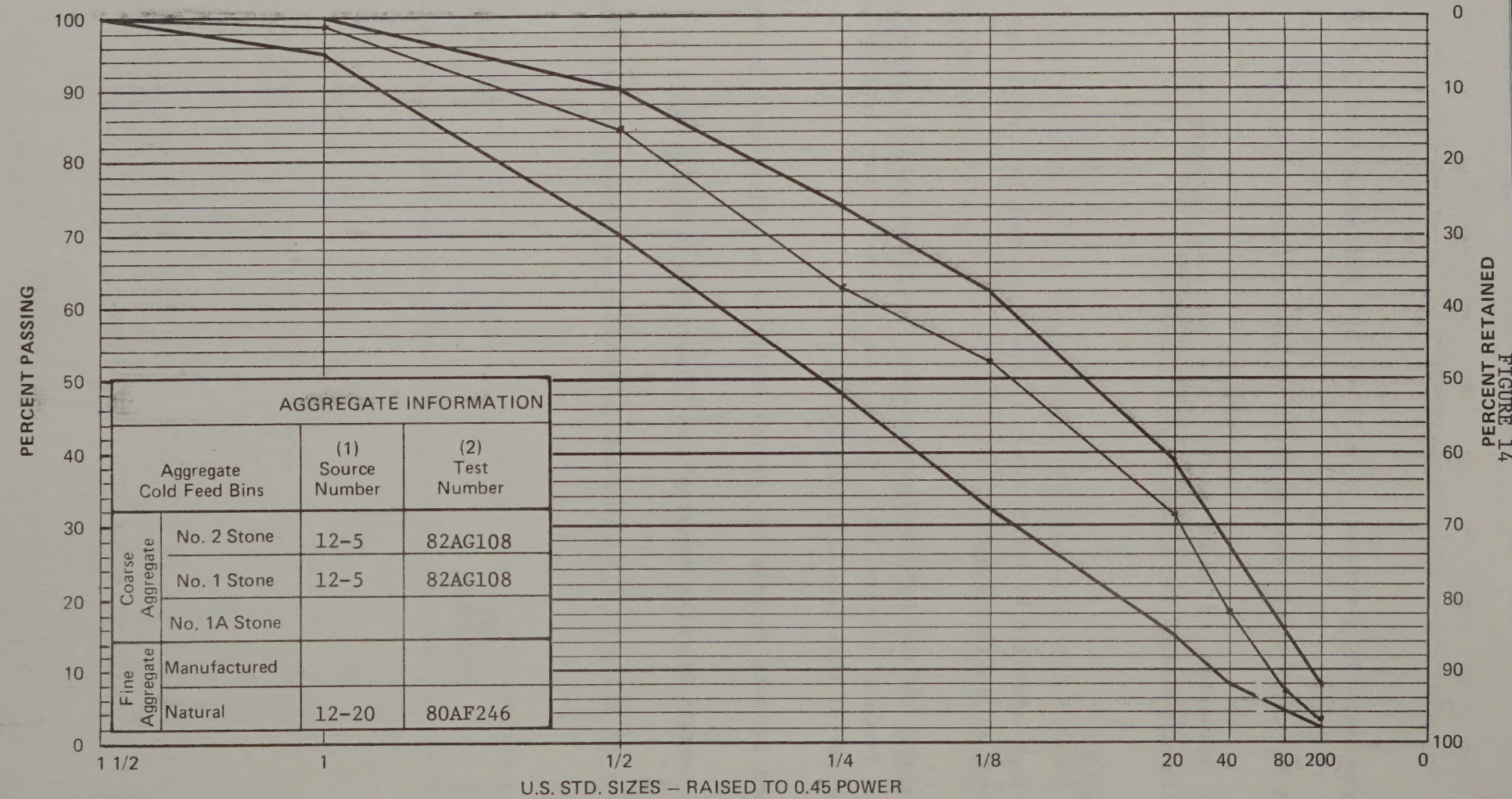


FIGURE 14

AGGREGATE INFORMATION			
Aggregate Cold Feed Bins		(1) Source Number	(2) Test Number
Coarse Aggregate	No. 2 Stone	12-5	82AG108
	No. 1 Stone	12-5	82AG108
	No. 1A Stone		
Fine Aggregate	Manufactured		
	Natural	12-20	80AF246

Sieve Size		2"	1 1/2"	1"	1/2"	1/4"	1/8"	No. 20	No. 40	No. 80	No. 200	Asphalt Content (Percent)
% Passing	1. General Limits		100	95-100	70-90	48-74	32-62	15-39	8-27	4-16	2-8	4.5-6.5
	2. JMF Range		100	95-100	79-90	56-70	46-60	24-38	11-25	4-11	2-5	
	3. Target Value		100	99	85	63	53	31	18	7	3	5.5(total)

Asphalt Grade Added
AC 10

Added Asphalt Content: 3.71 % RAP/New Aggregate Blend: 30/70

Approved _____

Regi... Direc...

BR 152 (11/83)

01470
LRI